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Increasing the Operating Consistency of the Finckh Pressurized Screen

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INCREASING THE OPERATING CONSISTENCY OF THE FINCKH PRESSURIZED SCREEN

by

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ABSTRACT:

The purpose of this study was to increase the operating consistency of The FINCKH pressurized screen. The main objective was to obtain good, efficient pulp cleaning at consistencies greater than 0.8%, and to observe the fractionating ability of the screen.

Cleaning efficiencies based on the removal of shives present in Groundwood were obtained in the order of 45%. Control runs were made at 0.7% consistency.

Installation of a linoleum volute - shaped element on the feed side of the screening zone, increased the velocity of the stock at low consistency (0.7%) without affecting the cleaning efficiency. At high consistency (1.26%) the volute induced excessive dewatering of the feed stock which led to total screen blinding. Different approaches to inducing high shear forces in the inlet side of the screening zone are recommended.

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INTRODUCTION:

Today's paper industry is very energy conscientious. Constant increases in the price of oil, steam, water and electricity make it imperative that process systems be highly energy efficient. The resultant advantages in a high-consistency pressurized screening system are: reduced decker, reduced space and horsepower requirements as well as reduced or eliminated screen dilution requirements.

HISTORICAL BACKGROUND AND DEVELOPMENT OF THE PROBLEM:

The primary purpose of a pulp screen is to create a mechanical condition where fibres react differently from the undesirable components in the pulp. Theoretically, a perfect screen should separate the feed into two components: one, containing all the good fibers called "ACCEPTS" and the other containing the undesirable material called "REJECTS".

Unfortunately this situation is not real; in most screens a large portion of fibers (mainly the long fiber portion) is rejected with the undesirables. Also, the accepts will contain some debris, and the concentration of these in the accepts portion determines screen EFFICIENCY.

There are several theories that attempt to explain how the screening takes place in a pressurized screen.

Kubát and Steenberg (4) have discussed the theory of pulp at low consistencies. Also, Kubát (5) presented very important views from the screening of pulp at high consistencies. He considers that fibers at high consistency form a mat on the screen plates and this mat, acting as the screening element lets the size of the screen holes appear smaller than they actually are. According to this, larger particles (such as shives) have a small probability of passing through the interstices of the mat and being accepted. Cowan (2) supports this theory by presenting experimental work in which he measured the number of slivers which were accepted through the screen plate and related that to the total number of slivers which were available to the screening operation. He then came up with a sliver density profile (radial) inside a pulp screen. Clarke-Pounder (1) offers a hypothesis to explain why and how the screening process takes place in which he suggests that adjacent to the feed side of the screen plate, three super-imposed, distinct fibrous zones of different characteristics, tend to exist. The first zone, P_1 is a dilute, good-fiber layer intimately in contact with the inlet side of the screen plate during normal operation. Maintenance of the P_1 layer by the continued replenishment of liquid and good fiber is considered mandatory for continuous screen operation. It is suggested that the replenishing liquid flows out of a relatively high consistency coarse fraction layer P_2 which is composed of long fibers, stiff fiber bundles and slivers. The P_2 layer would be possibly formed initially by vortex shear, in combination with the natural tendency for liquid to flow towards the screen plate due to the influence of differential pressure. Liquid and good fiber replenishment of the P_2 and P_1 layers must be provided by a third layer P_3 composed of whole pulp (a mixture of good fibers and a coarse fraction).

EFFECT OF CONSISTENCY ON SCREENING:

One of the main factors influencing pulp screening is consistency. It is easy to visualize that as consistency increases interaction among fibers and between fibers and shives will also increase.

The formation of clumps of fibers is noticeable even at low consistencies. Martin (6) did work on groundwood and proposed that as consistency increases in the screening zone, the area between fibers and a shive can change. A mechanism is needed to move fibers and shives so as to separate them. The higher the consistency, the more shives and fibers get entangled and therefore more shearing forces are needed to release the shives from the good fibers.

It is reasonable to suppose that in a pulp slurry there exists a tendency of isolated fibers to form bundles; as a result, forces which may be of chemical or physical nature are developed. Therefore, a fiber may have a chance or probability of passing through the screen perforation but in spite of being in the right position, it will not be able to pass through as long as it belongs to a bundle of larger size than the perforation. This means that the passage of a fiber through the screen plate will not only depend on a statistical probability but also on the behavior of the bundles created. The number of contacts between fibers depends on the average length of the fibers and the average distance between them, and a relation for this behavior is:

$$P = \frac{l}{A}$$

where P would be the number of potential contacts which a fiber of length l would come to if the average distance between the fibers is A. This means that for a given length the frictional forces developed by the fibers contacting each other is a function of consistency. At the same time, if consistency is kept constant, the frictional force between the fibers will be proportional to the length of the fibers. Tirado (9) developed equations to represent the probability that fibers of length l become interlaced within a bundle. He proposes that some of the factors which influence the intensity of the individual forces holding a bundle together are: the cooking (or refining) degree of the pulp, the flexibility or rigidity of fibers, their surface properties and the characteristics of the screening machine .

It is this last factor, the screen characteristics, that we will try to vary in our study to observe the change in operating consistency.

SHIVE REMOVAL FROM GROUNDWOOD USING SLOTTED SCREENS:

Seifert (8) tested three different kinds of pressurized screens using slotted baskets in order to improve shive and chop removal from groundwood pulp. He found that a slotted screen which features foils on the inlet side of the screen basket operated successfully and rejected undesirable material effectively. This screen performed signigicantly better than a standard hole-perforated screen used in a normal production operation and also much better than a reverse flow slotted screen which has foils on accepts side of the screen cylinder such as in the FINCKH pressurized screen. He offered a theory to explain the mechanism of shive rejection through preferential tangential alignment of shives. The means used to indicate screen performance were: measurement of the debries content of the reject sample as compared to the feed sample and comparison of Bauer-Mc Nett fractions for each sample. In his discussion Seifert explains that the effect of shive rejection in pressurized screens is based on the potential of tangential alignment of long debris in a screen where foils operate on the inlet side of the screen cylinder (Ex: Selectifier). An identical pulp in a reverse flow screen (FINCKH), where the foils are on the accepts side does not follow this alignment tendency because the foils never touch the feed. On the contrary, based on the poor shive rejection capability shown by this screen it was concluded that shives are oriented in such a way that they pass through the slotseasily. Also stock movement in such reverse flow screens proved to be very slow in the circumferential and axial directions. Seifert, through his work, turned in very important information on the theory of shive removal. His conclusions indicate that in a screen such as a Selectifier the mechanism for screening is not such as proposed by Kubat (5) or Cowan (2) in which a mat of fibers is theorized as responsible for the screening action. If this were true, he concludes, then the effeciency of a reverse flow screen would be higher because a mat of fibers is more likely to form in the less turbulent surroundings close to the basket. Martin (6) presented some theory in which he proposes that the high shear forces created by the foils rotating in the feed in the PS/PH or Selectifier screen are responsible for the alignment of most of the fibers and shives parallel with each other and tangential to the screen plate. This alignment, or brushing action, permits easier release of larger particles to prevent screen plugging. The periodic suction and pushing action of the foils also contribute to release undesirable particles at the moment the foil passes in front of a slot. Cleanliness of the accepted pulp, he proposes, is achieved not only by positive method of screening (i.e. by particle size), but also by further combining the probability method, and the dynamic method. The dynamic method proposed by Martin states that due to the dewatering process in the screen, the pulp will form a mat adjacent to the screen plate. In screens where a large part of this mat is rotating at a high velocity because of the action of the rotor, large shear forces exist in the screening zone adjacent to the screen plate. Because of these forces, the majority of the fibers will allign parallel with the screenplate. The stiff shives will enter a slot in the basket but when the tail end of it lifts up and lines perpendicular to the plate it is retrieved by the high velocity zone which forms the revolving mat. Fibers, being more flexible than shives will not behave in this manner and will pass through the slots.

In our work we support Martin's dynamic method of screening and consider it the basis for our experiment.

EXPERIMENTAL PROCEDURE:

The experimental work consisted of designing a volute-shaped element that was placed inside the screen on the inlet side of the slotted basket used (0.012" slots).

The purpose of the volute-shaped element is to increase the velocity of the stock in the screening zone adjacent to the basket and thus induce the shear forces necessary to obtain efficient shive removal.

The volute-shaped element was cut out of linoleum flooring and held in place by a hard foam fill (see fig 1). The volute was designed according to the following parameters:

1) The inlet (throat) area was calculated and for a predetermined volumetric flowrate (Q) a mean throat velocity V is calculated according to the equation $Q = VA$.

2) The different volute areas are assumed to have a constant mean velocity each, and the relationship between throat area (A thr) and volute areas (Av) is then:

$$Av = Athr \frac{\theta}{360}$$

where the intermediate volute areas are proportional to the central angle θ assuming also that the volute areas are circular. (See fig 2)

According to this equation, at a half revolution (180°), the velocity of the stock in the casing is twice of that at the throat therefore increasing the shear forces needed for high-consistency screening.

After the volute design was completed comparison runs were made with and without it istalled in the screen to determine the screening efficiency. The methods used for calculating shive removal efficiency are those as presented by Klemm (3) and Paterson (7) using a Bauer-Mc Nett classifier according to TAPPI standard T 233 OS-75 .

The calculations and equations taken from the literature are as follows:

INLET STOCK: Stock entering the screen and assigned a value of 100 so that all other streams may be expressed as a percentage relative to the feed.

GOOD STOCK: Stock passing through the 14-mesh screen in a Bauer- McNett classifier under TAPPI standard test conditions.

SHIVE (SLIVER) CONTENT: Percentage of stock retained on the 14-mesh screen in a Bauer-McNett classifier.

SPECIFIC ENERGY CONSUMPTION: Horsepower-day per ton of accepts (moisture-free) consumed by the screen.

Sr: Shive content or 14-mesh retention of rejects stream, %

Se: Shive content or 14-mesh retention of the inlet stock,%

Sa: Shive content or 14-mesh content of the accepted stream,%

Le: Long fiber content or 28-mesh retention of the inlet stream.

La: Long fiber content of the accepts stream or the percentage of stock retained on the 28- mesh screen in the Bauer-McNett classifier.

EQUATIONS:

Accepted stock (as percent of feed) = a = $100 \times \frac{Sr-Se}{Sr-Sa}$

Shive yield: (as percent relative) = screening efficiency

$$= 100 \times \frac{Sr}{Se} \, r$$

$$= 100 \times \frac{Sr(Se-Sa)}{Se(Sr-Sa)}$$

Good stock loss (as percent relative) = $100 - a \frac{(100-Sa)}{(100-Se)} = Yg$

Long fiber yield(as percent relative) = $YL = a \frac{La}{Le}$

Reject stock (as percent of feed) = $100 \times \frac{Se-Sa}{Sr-Sa} = r$

EXPERIMENTAL RUNS: See table 1 and figure 3 for operating conditions.

The experimental runs consisted of pulping batches of 100 lb O.D. of 75% Bleached H.W. Kraft and 25% Unbleached Groundwood. The pulping was done in a Hydrapulper (Black-Clawson) at 3% consistency and 150°F. The defibered pulp was then pumped to a holding chest where it was diluted and then pumped through the pressurized screen. Reject rate, temperature, dilution water, rotor peripheral speed, freeness, consistency and differential pressure across the screen were kept constant.

Shive content of the pulp supplied to the screen was kept constant by recirculating all the flows out of the screen back to the holding chest. Samples of inlet, accept and reject flows were taken and the volumetric flowrates were measured by registering the time needed to fill a 5-gal. bucket.

RESULTS:

The experimental runs showed the following results:

1) In the runs without the volute, increasing the feed rate and decreasing the reject rate did not influence screen efficiency significantly. See table 4.

2) The installation of the volute did not affect screening efficiency significantly at low consistency (0.7%). See table 4.

3) Screening with the volute installed could not be done at high consistency (1.26%). A pressure drop across the screen could not take place between the inlet and accepts sides of the screen.

DISCUSSION OF RESULTS:

The results of screening at low consistency (0.7%) show that the shear forces necessary for the efficient removal of "shives" are present although not in an optimum condition.

The screening efficiencies obtained at these low consistencies were in the order of 45%. This means that more than half of the "shives" introduced into the screen were accepted which also indicates that the FINCKH screen is a poor fiber fractionator. Clearly this is not a desirable situation if the FINCKH screen is to be used effectively in industrial applications. At low pulp consistencies it should be easier for the screen to separate shives from "good" pulp because fiber-to-fiber interactions are less frequent.

As we have postulated, in the FINCKH screen, the lack of large shear forces in the screening zone affect efficiency as less turbulence is available to retract the stiff shives from the slots once they have started going through them. It was interesting to find that the introduction of the volute into the screening zone did not increase efficiency even though theoretically if the area through which the inlet stock moves is decreased, then velocity should increase, and therefore more turbulence would be induced. This turbulence should have at the same time created high-intensity forces within the stock that should have helped in the rejection of shives. The effect of the volute on the stock was only to increase its velocity but it did not induce the shear forces desired. This effect is shown by an increase in feed rate with constant reject rate and efficiency. At high consistency however the benefit of higher throughput did not compensate for the excessive dewatering and matting of pulp in the screening zone.

The cause of blinding at high consistency can be explained as follows:

In the FINCKH screen, dewatering of the feed occurs adjacent to the screen basket. This dewatering forms a mat of fibers that helps in the screening action. If the consistency of the feed stock is increased and the area available for this pulp to move and interact is decreased, it is only logical to expect that fiber-to-fiber interactions and dewatering of this stock will occur. In the experiment with the volute, at high-consistency, this stock "crowding" and excessive dewatering caused the basket to blind soon after the rejects valve started closing to establish a pressure drop across the screen. After blinding, the screen was opened and a very thick mat of fibers could be observed outside the basket which prevented free flow of stock around the latter. These observations verified the inability of the volute to induce the levels of shear needed for high consistency screening. What all these facts tell us is that other methods are necessary to induce high shear forces into the inlet side of the FINCKH pressurized screen.

CONCLUSIONS:

The results of this study have shown that high consistency screening with a FINCKH pressurized screen cannot be done unless an effective way to induce high shear forces in the screening zone adjacent to the basket is found. The fractionating ability of the screen is not good enough to produce two grades of short and long fiber from the same furnish in a single step.

RECOMMENDATIONS:

It is the author's opinion that further work geared towards increasing the operating consistency of the FINCKH pressurized screen would not prove succesful unless major changes are done to the present machine design. The possibility of changing the rotor design was one of the first ideas brought up to do the job, but it is our belief that in a reverse flow screen no matter what type of rotor is used it will not induce the shear forces desired on the feed side of the screening zone.

ACKNOWLEDGMENT:

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T A B L E 1

RUN	VOLUTE INSTALLED	FLOWS (gpm) FEED	FLOWS (gpm) ACCEPTS	FLOWS (gpm) REJECTS	CONSISTENCIES (%) FEED	CONSISTENCIES (%) ACCEPTS	CONSISTENCIES (%) REJECTS
I	NO	30.0	16.9	12.9	0.65	0.80	0.40
II	NO	33.33	25.4	7.8	0.69	0.76	0.45
III	YES	37.5	30.0	9.52	0.73	0.76	0.55
IV	YES	—	—	—	1.26	—	—

For all runs:

Stock Freeness: 500 ml C.S.F

Pressure Drop across screen: 3 psig (Inlet pressure = 30 psig
Accepts pressure = 27 psig)

Stock Temperature: $\pm 100°F$

55% Load Motor Current.

T A B L E 2

B A U E R - McN E T T C L A S S I F I C A T I O N S

10 g. Sample (15 minutes retention time).

RUN I:		14 mesh retention (g.)	28-mesh retention (g.)
1)	Feed	1.28	3.28
	Accepts	1.51	3.38
	Rejects	1.10	4.10
		Efficiency = 48.2%	
2)	Feed	1.25	3.40
	Accepts	1.70	3.50
	Rejects	1.00	-
		Efficiency = 51.4%	
3)	Feed	1.30	3.90
	Accepts	1.90	3.20
	Rejects	0.90	2.80
		Efficiency = 41.5%	

Mean "shive" content* of Run I = 1.30 g/10g sample.

* 14-mesh retention of inlet (feed) stream.

T A B L E 2

RUN II:		14-mesh retention (g.)	28-mesh retention (g.)
1)	Feed	1.18	2.78
	Accepts	1.58	3.18
	Rejects	0.98	3.50
		Efficiency = 55.4%	
2)	Feed	1.18	3.18
	Accepts	1.30	3.00
	Rejects	11.05	3.80
		Efficiency = 42.7%	
3)	Feed	1.20	2.90
	Accepts	1.40	3.00
	Rejects	1.00	-
		Efficiency = 41.7%	
4)	Feed	1.40	2.90
	Accepts	1.90	3.30
	Rejects	0.90	2.90
		Efficiency = 32.1%	

Mean "shive" content of Run II = 1.24 g/10g. sample.

TABLE 2

RUN III :		14-mesh retention (g.)	28-mesh retention (g.
1)	Feed	1.20	2.78
	Accepts	1.60	3.20
	Rejects	1.00	3.50
		Efficiency = 55.6%	
2)	Feed	1.50	3.10
	Accepts	1.90	3.40
	Rejects	0.99	3.45
		Efficiency = 29%	
3)	Feed	1.30	3.30
	Accepts	1.48	3.35
	Rejects	1.10	4.00
		Efficiency = 40.1%	
4)	Feed	1.30	3.40
	Accepts	1.60	3.40
	Rejects	1.00	3.80
		Efficiency = 38.5%	
5)	Feed	1.20	2.30
	Accepts	1.50	3.10
	Rejects	0.95	3.30
		Efficiency = 43.2%	

Mean "shive" content of Run III = 1.3 g./10g. sample.

TABLE 3

MATERIAL BALANCES (O.D. FIBER BALANCE)

RUN I:

$$\text{Feed: } \frac{5\text{ gal}}{10\text{ sec}} \times 60 \times \frac{1}{7.48} \times 62.4 \times \frac{0.65}{100} = 1.63\ \frac{\text{lb O.D. fiber}}{\text{min}}$$

$$\text{Accepts: } \frac{5\text{ gal}}{17.8\text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.81}{100} = 1.14\ \frac{\text{lb. O.D. fiber}}{\text{min}}$$

$$\text{Rejects: } \frac{5\text{ gal}}{23.3\text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.40}{100} = 0.43\ \frac{\text{lb. O.D. fiber}}{\text{min}}$$

Feed = Accepts + Rejects

$1.63 \approx 1.14 + 0.43$ 4% error

RUN II:

$$\text{Feed: } \frac{5\text{ gal}}{9\text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.69}{100} = 1.92\ \frac{\text{lb. O.D. fiber}}{\text{min}}$$

$$\text{Accepts: } \frac{5\text{ gal}}{11.8\text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.71}{100} = 1.61\ \frac{\text{lb O.D. fiber}}{\text{min}}$$

$$\text{Rejects: } \frac{5\text{ gal}}{38.4\text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.45}{100} = 0.29\ \frac{\text{lb O.D. fiber}}{\text{min}}$$

Feed = Accepts + Rejects

$1.92 \approx 1.61 + 0.29$ 1% error

TABLE 3

RUN III:

Feed: $$\frac{5 \text{ gal}}{8 \text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.73}{100} = 2.28 \ \frac{\text{lb. O.D. fiber}}{\text{min}}$$

Accepts: $$\frac{5 \text{ gal}}{10 \text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.76}{100} = 1.90 \ \frac{\text{lb. O.D. fiber}}{\text{min}}$$

Rejects: $$\frac{5 \text{ gal}}{31.5 \text{ sec}} \times 60 \times \frac{62.4}{7.48} \times \frac{0.55}{100} = 0.44 \ \frac{\text{lb.O.D. fiber}}{\text{min}}$$

Feed = Accepts + Rejects

$2.28 \approx 1.90 + 0.44$ 3% error

T A B L E 4

S T A T I S T I C A L A N A L Y S I S

STATISTICAL COMPARISON OF EFFICIENCIES:

RUN	$\bar{X}$ (efficiency)	n	s
I	47%	3	5.05%
II	43%	4	9.56%
III	41.3%	5	9.60%

<u>COMPARISON OF RUNS I AND II:</u>

Estimate of = s (pooled) = $\dfrac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2 - 2}$

$$s_p^2 = \frac{2\,(5.05)^2 + 3(9.56)^2}{3+4-2} = 65$$

$$s_p = \sqrt{65} = 8.06$$

<u>Null Hypothesis (Ho):</u> $\bar{x}_1 = \bar{x}_2$ (i.e. There is no difference between the efficiencies of Run I and Run II)

Ho: $\bar{x}_1 = \bar{x}_2$

H_1: $\bar{x}_1 \neq \bar{x}_2$

Reject Ho if $t < -t(\alpha/2, n_1+n_2-2)$ or if $t > t(\alpha/2, n_1+n_2-2)$

$t(\alpha/2, n_1+n_2-2) = 2.571$ for 6 degrees of freedom.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s_p\sqrt{\frac{1}{m_1}+\frac{1}{m_2}}} = \frac{47 - 43}{8.06\sqrt{\frac{1}{4}+\frac{1}{3}}} = 0.65$$

$0.65 < 2.571$ so we <u>fail to reject</u> Ho at 95% confidence level

T A B L E 4

i.e. $\boxed{\bar{x}_1 = \bar{x}_2}$. Increasing the feed rate and decreasing the reject rate did not influence the cleaning efficiency statistically.

COMPARISON OF RUNS I AND III:

$n_1 = 3 \quad n_2 = 5$

$$s_p^2 = \frac{2\,(5.05)^2 + 4(9.60)^2}{6} = 69.9 \qquad s_p = 8.36$$

$t(\alpha/2,\ n_1 + n_2 - 2) = t(0.025,\ 6) = 2.447$ for 6 degrees of freedom.

$$t = \frac{47 - 41.3}{8.36\sqrt{\frac{1}{3} + \frac{1}{5}}} = 0.93$$

$0.93 < 2.447$ so we fail to reject Ho at 95% confidence level and we can say that the installation of the volute did not influence the cleaning efficiency statistically.

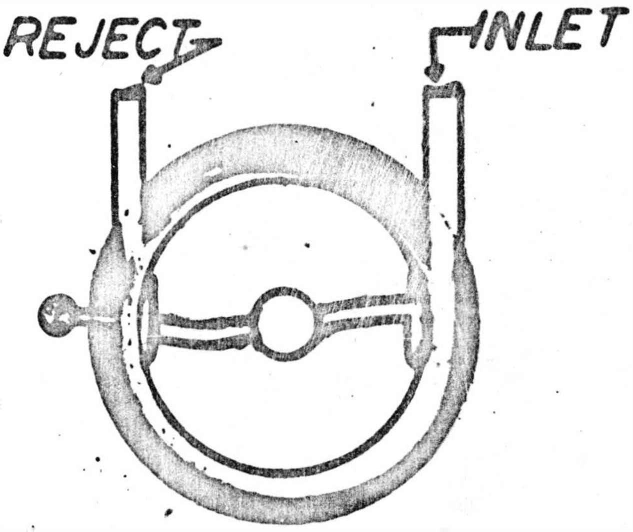


fig 1

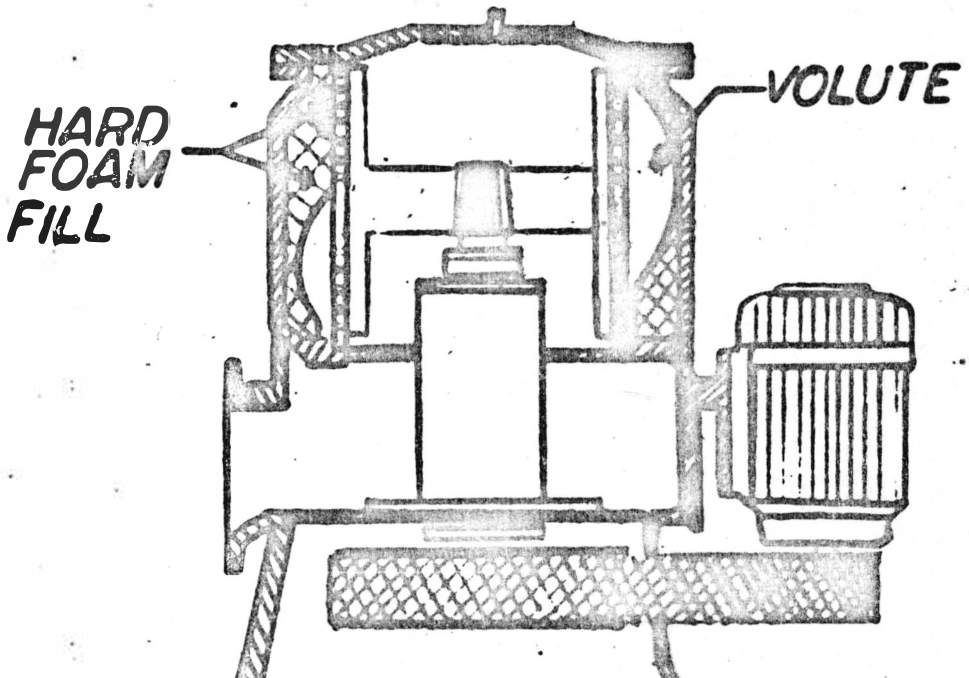


fig 2

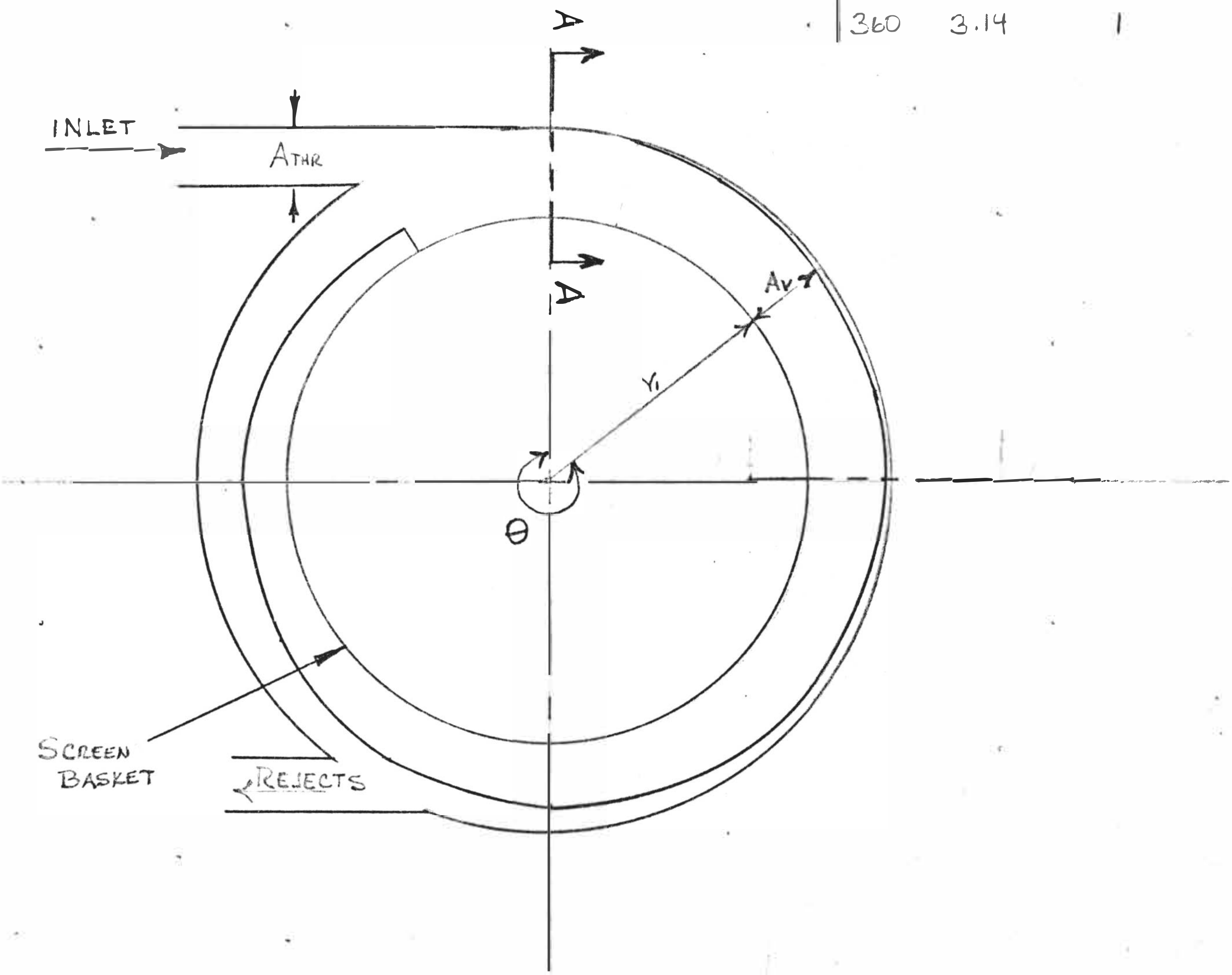
FINCKH
SCREEN

FIGURE 2

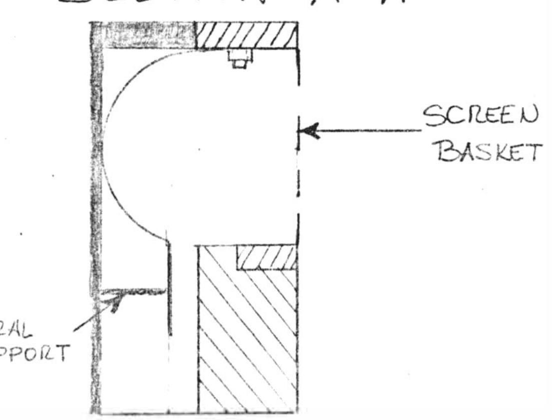
$$A_V = A_{THR}\,\frac{\theta}{360}$$

$$A_{THR} = \pi\,\frac{(2)^2}{4} = 3.14\ in^2$$

θ	A_V (in²)	r (in)
0°	0	0
90°	0.786	0.50
180°	1.572	0.707
360	3.14	1



SECTION A-A



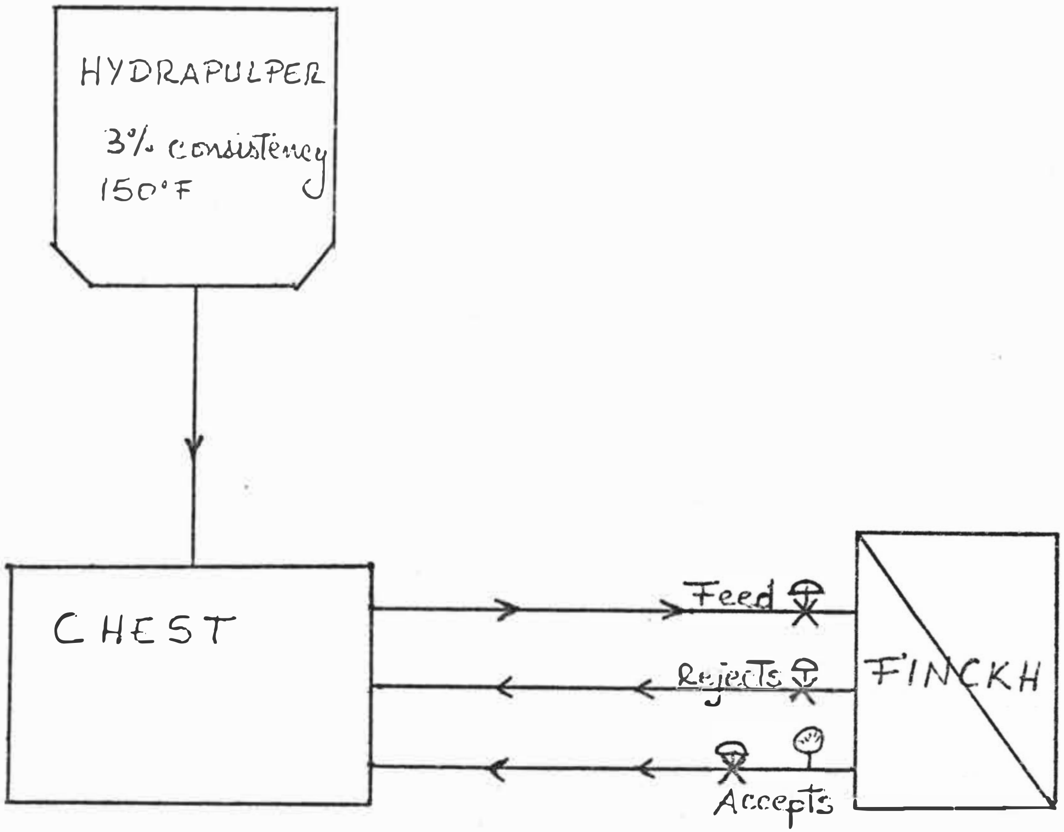

HYDRAPULPER
3% consistency
150°F
CHEST
Feed
Rejects
Accepts
FINCKH

FIGURE 3